Wheat was small and backward at the close of the month, but had made rapid improvement in condition, especially in the middle and western divisions. The work of sowing oats and breaking and preparing land for corn and cotton was about finished and a considerable acreage in corn was planted. Irish potatoes were planted and gardening was well advanced.—*H. C. Bate.*

*Texas.*—The mean temperature was 58.6°, or 0.3° below normal; the highest was 103°, at Fort Ringgold on the 9th, and the lowest, 12°, at Anna on the 6th and Haskell on the 10th. The average precipitation was 1.43, or 0.58 below normal; the greatest monthly amount, 5.44, occurred at Arthur City, while none fell at Eagle Pass, Fort Brown, and Sanderson.

Except in the eastern portion of the State, where the rainfall was sufficient for agricultural purposes, the weather conditions were generally unfavorable for farming interests. At the close of the month rain was badly needed over the western portion of the State for all interests. Wheat and oats suffered for the want of rain, and insects damaged these crops seriously in many localities. The bulk of the corn crop was planted, but good stands were not secured in all sections. Good progress was made in the preparation of land for cotton, but the majority of farmers are waiting for good rains before planting. Trucking interests suffered generally on account of the dry weather. The strawberry crop was cut short. A good acreage has been planted to sugar cane. Preparations are being made for a large rice crop.—*I. M. Cline.*

*Utah.*—The mean temperature was 36.8°, or 1.1° below normal; the highest was 78°, at Moab on the 2d and at St. George on the 6th, and the lowest, 2° below zero, at Soldier Summit on the 30th. The average precipitation was 0.84, or 0.48 below normal; the greatest monthly amount, 3.15, occurred at Park City, while none fell at Kanab.—*L. H. Murdoch.*

*Virginia.*—The mean temperature was 46.6°, or 3.0° above normal; the highest was 83°, at Ashland on the 26th, and the lowest, 3° below zero, at Burkes Garden on the 6th. The average precipitation was 3.49, or 0.43 below normal; the greatest monthly amount, 5.73, occurred at Callaville, and the least, 1.29, at Manassas.

Favorable conditions of temperature and moisture prevailed, and winter grains, which had been suffering from drought and were backward, made excellent growth and at the close of the month were nearly normal in condition.—*Edward A. Evans.*

*Washington.*—The mean temperature was 42.5°, or 2.1° above normal; the highest was 84°, at Dayton on the 21st, and the lowest, 16° at Republic on the 5th. The average precipitation was 2.59, or 0.34 below normal; the greatest monthly amount, 10.40, occurred at Monte Cristo, and the least, 0.06, at Ritzville.

The first three weeks were very mild and favorable but the cool and wet character of the last week of the month was unfavorable for spring work and the growth of crops, making the spring late and crops backward—*G. N. Salisbury.*

*West Virginia.*—The mean temperature was 42.9°, or 0.5° above normal; the highest was 83°, at Point Pleasant on the 24th, and the lowest, 11° below zero, at Terra Alta on the 6th. The average precipitation was 3.23, or 0.56 below normal; the greatest monthly amount, 5.27, occurred at Harpers Ferry, and the least, 0.90, at Parsons.

Practically no snow protection and almost constant freezing and thawing, but wheat generally reported in fair condition; considerable late sown winter-killed and some plowed up; farm work well advanced; some oats being sown and gardens made; some potatoes, onions, and peas already planted; just cold enough to retard budding, and fruit prospects excellent; cattle and sheep wintered fairly well, but feed getting scarce.—*E. C. Vose.*

*Wisconsin.*—The mean temperature was 28.1°, or about normal; the highest was 64°, at Grantsburg on the 16th, and the lowest, 38° below zero, at Butternut on the 6th. The average precipitation was 2.85, or 1.00 above normal; the greatest monthly amount, 5.15, occurred at Port Washington, and the least, 1.55, at West Bend.

A very damaging sleetstorm occurred on the 10th. The telephone and telegraph wires became so burdened by the accumulation of ice that hundreds of miles of wire in the southern portion of the State were borne to the ground, and Milwaukee was practically cut off from the outside world for nearly forty-eight hours. No progress has been made in farm work, the ground being still frozen in many portions of the State.—*W. M. Wilson.*

*Wyoming.*—The mean temperature was 30.3°, or 1.2° above normal; the highest was 70°, at Buffalo on the 1st, and the lowest, 10° below zero, at Daniel on the 30th and 31st. The average precipitation was 0.87, or 0.49 below normal; the greatest monthly amount, 2,45, occurred at Saratoga, and the least, trace, at Hyattville and Basin.

The mild weather of March allowed some plowing and seeding to be done over some parts of northern Wyoming.—*W. S. Palmer.*

*Cuba.*—The mean temperature was 73.7°; the highest was 98°, at Holguin on the 23d, and the lowest, 42°, at Batabano on the 18th. The average precipitation was 1.42; the greatest monthly amount, 2.94, occurred at Soledad (Guantanamo), and the least, 0.15, at Holguin.

The precipitation was light but fairly well distributed; it caused very few interruptions in cane harvest, and grinding continued throughout the month. Preparations of soil for spring cane planting was generally and actively carried on; planting is under way at scattered points. New canes and stubble did not receive sufficient rain but they very satisfactorily withstood the effects of the dry weather. The tobacco harvest was finished in Pinar del Rio and western Havana during the first fifteen days of the month; the yield was short but the quality is considered very good; the weather was too dry to admit of handling the crop and but little selecting was under way at the end of the month. Tobacco in Santa Clara improved greatly and yield and quality will prove better than anticipated. Rainfall was entirely too light for small crops, especially in Pinar del Rio. Quite seasonable temperature prevailed.—*Wm. B. Stockman.*

## SPECIAL CONTRIBUTIONS.

### FOG STUDIES ON MOUNT TAMALPAIS: NUMBER 4.[1]

By ALEXANDER G MCADIE, Forecast Official, dated January 25, 1901.

REFRACTION OF SOUND WAVES BY FOG SURFACES.

In a previous paper the aberration of the zones of audibility of fog signals was briefly referred to in connection with the fog billows formed at the common surface of air streams of different temperatures and densities. Some photographs of these Helmholtzian air billows, or rather of the vapor masses which serve as exponents of the air waves, were given, and the question of the reflection and interference of sound waves in the vicinity of Mount Tamalpais briefly alluded to. In the present paper some additional photographs showing rather remarkable curved surfaces of the condensed water vapor are given.

The velocity of sound, it is generally stated, is within wide limits practically independent of both intensity and pitch. In dry air at 0° C., according to Rowland, the velocity of sound propagation is 331.78 meters (1,090 feet) per second. In water vapor at 10° C., according to Masson, the velocity is about 402 meters (1,318 feet), and at 96° C. 410 meters (1,345 feet) per second. In water at 10° C. the velocity is about 1,435 meters (4,708 feet); in copper about 3,560 meters and in glass from 5,000 to 6,000 meters.

The velocity is proportional to the square root of the absolute temperature, as given by the formula,

$$a = a_0 \sqrt{1 + \frac{\theta'}{273}}$$

where $a$ = velocity of sound

$a_0$ = velocity of sound at 0° C.

The velocity of sound propagation in dry air is therefore about 37 times more rapid than that of the average summer afternoon winds (20 miles per hour), which blow through the Golden Gate with such regularity and which are the prime disturbing factors in the circulation of the air in this vicinity. The question of refraction of sound in free air has been independently studied by Stokes[2], Taylor[3], Henry[4], Tyndall[5], and Reynolds[6], and many of the puzzling phenomena connected with the aberration of sound can be demonstrated to be caused by the bending of the sound beams in traversing air strata of varying temperatures and motions. The most efficient cause of loss of audibility is

[1] The Editor regrets that the publication of this article, written before the loss of the steamship *Rio de Janeiro*, has been delayed by waiting for the half-tone plates.

[2] Report British Association, 1857. [3] Smithsonian Report, 1875. [4] Smithsonian Report, 1877. [5] Philosophical Transactions, 1874. [6] Philosophical Transactions, 1876.

wind. The loss is not due to an actual retardation of the sound waves by the movement of the air so much as to a refraction of the wave front upward from the earth. Sound traveling with the wind is bent downward, and traveling against the wind is bent upward. Knowing this, we are able, by lifting the position of the hearer, sometimes to make sound audible against the wind. Thus Henry shows that a sound moving against the wind, inaudible to the ear on the deck of a vessel, could be heard at the masthead. Reynold's experiments even more conclusively demonstrate the bending of the wave front downward as a rule when moving with the wind, and upward when moving against the wind.

The accompanying photographs, Plate I, figs. 1 and 2, show air strata moving with varying velocities. As a rule the upper currents have the greater velocity, but not infrequently this condition may be reversed. In such cases audibility should be favored, even by an opposing wind. And this is sometimes found to be the case. Thus far we have alluded only to the refraction of the wave fronts due to varying air velocities. But the varying temperatures of the different air masses will also affect the relative audibility. Reynolds instances a marked case, where owing to a thorough cooling of the lower air strata, and presumably a marked inverted temperature gradient, the audibility was excellent, the sound being refracted downward, and all objects "looming" as it were. It is even possible to work out the retardation or acceleration of the wave front with the degree of variation in temperature. Finally, it may be that the temperature and the air motion may act together to refract downward the sound wave, and it may also happen that the one influence may oppose the other. Thus Reynolds gives an example where, with a heavy dew on the ground, sound could be heard equally well against a light wind as with the wind,

Showing that the upward refraction by the wind was completely counteracted by the downward refraction from the diminution of temperature. This was observed not to be the case when cloudiness at night prevented terrestrial radiation. (Proc. R. S., 1874.)

The presence of large quantities of condensed water vapor brings us to the question of refracting surfaces, and the reverberation of the sound rather than its velocity.

When a sound wave travels over a perfectly smooth surface such as a glassy sea, or a sharply outlined plane of condensation, the intensity of the sound does not diminish with the usual rapidity. In discussing the propagation of sound in whispering galleries, Rayleigh[7] shows that the abnormal loudness is not confined to a point diametrically opposite that occupied by the speaker, but that there is a bending or clinging of the sound waves to the surface of the concave wall. Sonorous vibrations at fog surfaces and cloud surfaces may behave in a somewhat similar way, and it is probable that the curvature of the surface is not of as great importance as the comparative smoothness of the surface. Probably the roll of thunder is an excellent illustration of continued reverberation at cloud surfaces.

## DISSIPATION OF FOG.

Our discussion of fog phenomena will be incomplete without some reference to the question of the dissipation of fog. What is greatly needed, however, is a systematic study of the various methods known to be effective in dissipating or scattering fog particles. Dr. Lodge has pointed out a number of different methods by which dust can be removed from the air, and it is now generally believed that by removing dust the essential nuclei of condensation are removed. The various methods may be briefly described as filtering, settling, recondensing, calcining, and electrifying. Of all these the last mentioned seems to offer most in connection with the problem of fog dissipation. To dissipate the fog, we can either by gentle electrification increase the size of the dust nuclei or, under strong electrical discharges, rupture and precipitate the same. In one of Dr. Lodge's lectures before the British Association at Montreal occurred the following pointed reference to fog dissipation:

It seems not impossible that some use may be made of this aggregating power of electricity on small bodies, such as smoke particles and mist globules. In coming to this country, we lay for some hours outside the Straits of Belle Isle in the midst of icebergs mingled with fog. Icebergs alone are not dangerous, but beautiful. Fog is an unmitigated nuisance. Electric light is powerless to penetrate it; and it was impossible, as we lay there idle, not to be struck with the advisability of dissipating it. It is rash to predict what can not be done. I would merely point out that on board a steamer are donkey engines [Dr. Lodge could now add dynamos and the means of generating powerful currents of electricity] and that these engines can drive a very powerful Holtz or Wimshurst machine, one pole of which may be led to points on the masts. When electricity is discharged into fog on a small scale, it coagulates into globules and falls as rain; perhaps it will on a large scale, too. Oil stills the ripples of a pond and it has an effect on ocean billows; just so an electric discharge, which certainly coagulates and precipitates smoke or steam in a bell jar, may possibly have an effect on an Atlantic fog. I am not too sanguine, but it would not cost much to try, and even if it only kept a fairly clear place near the ship it would be useful.

The author has elsewhere described certain experiments made at the top of the Washington Monument, Washington, D. C., wherein some noteworthy relations between flashes of lightning and the character of a stream of water issuing from the nozzle of a Thomson collector were described. Previous to each flash the jet would be twisted and split into many fine streams and sprays, but instantly with the occurrence of the flash the stream resumed its normal character. In this case many of the experiments of the laboratory were verified by experiments made under natural conditions.

The subject is certainly interesting enough to warrant further study. Lord Rayleigh has shown that remarkable effects are obtained by bringing a highly electrified body near a fine stream of water, and has stated[8] that—

There is a practical application in meteorology of these relations. The formation of rain must depend very materially upon the consequences of encounters between cloud particles. If encounters do not lead to contact, or if contacts result in rebounds, the particles remain of the same size as before; but if the issue be coalescence, the bigger drops must increase in size and be precipitated as rain.

In very recent years a theory advanced by T. C. R. Wilson in connection with the origin of atmospheric electricity has brought prominently into notice the efficiency of the ions as nuclei of condensation of water vapor. Wilson[9] finds that positive and negative ions (at least those produced in air by Röntgen rays) differ in efficiency as condensing nuclei. Elster and Geitel in their long series of papers upon atmospheric electricity have shown that normal air contains positive and negative ions in nearly equal quantities. Zeleny has shown that the negative ions move more rapidly. It is also known that in liquids the ions travel with the atoms, while in gases the ions appear to be free. In brief, the substance of the theory advanced by Elster and Geitel and elaborated by Wilson is that the ultraviolet rays of sunlight ionize the upper air strata, and owing to various causes the ions will in time distribute themselves somewhat as follows, the negative ions in the lower strata chiefly and the positive ions above. Water vapor will condense more rapidly on the negative than on the positive ions. The negative ions become centers of condensation with a less degree of supersaturation. Aitken has objected to the theory and raises the question as to whether the necessary supersaturation does occur in fact, and whether there is a sufficiently dust free atmosphere. Wilson thinks that the air may be purified of its dust by an ascensional movement. Aitken, however, thinks that when

[7] Theory of Sound, Vol. 2, Sec. 287.

[8] Proc. R. S., March 13, 1879. [9] Nature, March 29, 1900.

a cloud forms in ordinary impure air only a small proportion of the dust centers become active centers of condensation. He has counted on the Rigi Kulm as many as 4,000 dust particles per cubic centimeter in clouds and 7,700 in dense clouds. while in fog there are as many as 50,000. While it is not probable that the ions could cause the formation of cloud, they might give rise to rain. When the air is in a certain unstable condition any ion more active than others will grow rapidly and falling through highly saturated air will relieve the tension along its path, and we may thus have an active cause in the formation of a raindrop.

From all that precedes, it is evident that the processes at work in the formation of a raindrop are exceedingly intricate, but with a rapidly increasing knowledge of physical relationships it does not seem hopeless to undertake elaborate experiments to determine the active agencies in what may be called the field of collapse. At Mount Tamalpais, as we have tried to show, fog conditions are pronounced, saturated and supersaturated strata lie in close juxtaposition and seemingly are within reach of experimentation.

## PRESSURE OF SATURATED AQUEOUS VAPOR AT TEMPERATURES BELOW FREEZING.

By Prof. MAX THIESEN, dated Friedrichshagen, January 12, 1899, from the Ann. dr Phys. u. Chem., March, 1899, vol. 67, pp. 690-695.

The following computations were made in order to investigate how far much more accurate determinations of the pressure of aqueous vapor than at present exist would be of interest at low temperatures. At first the temperature itself was determined, for which the difference in the pressures over water and over ice becomes a maximum, then the absolute pressures themselves for both cases were computed. Some of the relations that resulted in this work will not be without interest to others.

We first establish the equation of condition for the temperature when the maximum difference occurs; that such a maximum in general must occur follows from the fact that the difference between the two conditions over water and over ice is inappreciable both in the neighborhood of 0° C. and also at very low temperatures.

Let $v_1$ and $v_2$ be the volumes of the vapor and the fluid at the absolute temperature $T$; $p$ the pressure of the saturated vapor in contact with the fluid; $\rho$ the latent heat of evaporation of water; and let the corresponding quantities for ice be indicated by indices; then, according to Clapeyron and Clausius,

$$(1)\qquad (v_1 - v_2)\frac{dp}{dT} = \frac{\rho}{T};$$

$$(2)\qquad (v_1' - v_2')\frac{dp'}{dT} = \frac{\rho'}{T}$$

When the difference between the two vapor pressures is a maximum, the change or differential of $p - p'$ with respect to $T$ becomes 0; consequently, at this point we have

$$(3)\qquad \frac{v_1' - v_2'}{v_1 - v_2} = \frac{\rho'}{\rho}.$$

An approximation that will be demonstrated hereafter is now introduced into the preceding rigorous formula by the assumption that, corresponding to the Marriott and Gay-Lussac law, we may assume—

$$(4)\qquad p(v_1 - v_2) = p'(v_1' - v_2') = R\,T.$$

The equations (1), (2), (3) now become—

$$(5)\qquad \frac{d \log p}{d\,T} = \frac{\rho}{R\,T^2}$$

$$(6)\qquad \frac{d \log p'}{d\,T} = \frac{\rho'}{R\,T^2}$$

$$(7)\qquad \frac{p}{p'} = \frac{\rho'}{\rho}$$

If, now, we indicate by $T_0$ the temperature, which lies only a little above 0° C., for which $p' = p$, then by the subtraction of (6) from (5), followed by integration, we have—

$$\log \frac{p}{p'} = -\int_{T_0}^{T} \frac{\rho' - \rho}{R\,T^2}\,d\,T$$

and by connecting this with equation (7) we have, finally:

$$(8)\qquad \log \frac{\rho'}{\rho} = -\int_{T_0}^{T} \frac{\rho' - \rho}{R\,T^2}\,d\,T.$$

From this equation the location of the maximum can be determined with sufficient accuracy; to this end the individual quantities entering into the equation must be studied more closely.

The quantity $(\rho' - \rho)$ is the latent heat of liquefaction of ice; it may be designated by $\sigma$. The variation of this quantity with temperature and under constant pressure (as we may here assume without appreciable error) is given by the expression—

$$d\,\sigma = (C - C')\,d\,T$$

in case C and C′ are the specific heats of water and ice under constant and inappreciably small pressure.

The numerical values of $\sigma$, $C$ and $C'$ in the neighborhood of 0° C. are given in calories as follows:

$$(9)\qquad \sigma_0 = 79.9;\ C = 1;\ C' = 0.474;$$

hence the heat of liquefaction increases for each degree by 0.526 calories, or 0.0066 of its own value, or almost at the same rate as $T^2$; with a little greater accuracy we may write

$$(10)\qquad \frac{\sigma}{T^2} = \frac{\sigma_0}{T^2}(1 - 0.007\,t)$$

where we, for the sake of brevity, have put $t = T - T_0$. The right-hand side of equation (8) has, therefore, the value:

$$-\frac{\sigma_0}{R\,T_0^2}(1 - 0\,0004\,t)t.$$

In order to compute the quantity $\sigma_0/R\,T_0^2$, which occurs herein, we propose the two following methods:

(A). We convert the above value of $\sigma_0$ into mechanical units by multiplying it by 41.34, where the atmospheric pressure is considered as the unit of pressure and compute the value of $R$ from the corresponding value for carbonic acid gas, as it results from Regnault's observations[1], after reduction with the latest values of the atomic weights. We thus obtain:

$$(11)\qquad \frac{\sigma_0}{R\,T_0^2} = \frac{79.9 \times 41.34 \times 0.2200}{273^2} = 0.00975.$$

(B.) By means of equation (5) we rewrite the expression just computed in the following form:

$$\frac{\sigma_0}{R\,T_0^2} = \frac{\sigma}{\rho} \times \left[\frac{d \log p}{d\,T} \text{ at } 0^\circ \text{ C.}\right]$$

We compute the value of $\rho$ for the temperature 0° C., from the expression [2]

$$(12)\qquad \rho = r\,(\tau - T)^{1/3}$$

where[3] Log. $r = 1.9214$, $\tau - T_0 = 365$, whence $\rho_0 = 596.3$ (calorics.)

For the computation of the second factor I use the following equation:

[1] M. Thiesen. Wiedemann's Annalen. 1885. Vol. XXIV, p. 483.

[2] M. Thiesen Sitzungsb. d. Phys. Gesell. zu Berlin. 1897. Vol. XVI, p. 80.

[3] I uniformly designate the natural logarithms by log and the ordinary Briggian logarithms by Log.

Fig. 1.

Fig. 2.